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Learning what to remember: vocabulary knowledge and children's memory for object
names and features

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Abstract

Although young children can map a novel name to a novel object, it remains unclear what they actually remember about objects when they initially make such a name-object association. In the current study we investigated 1) what children remembered after they were initially introduced to name-object associations and 2) how their vocabulary size and vocabulary structure influenced what they remembered. As a group, children had difficulty remembering each of the features of the original novel objects. Further analyses revealed that differences in vocabulary structure predicted children's ability to remember object features. Specifically, children who produced many names for categories organized by similarity in shape (e.g., ball, cup) had the best memory for newly-learned objects' features—especially their shapes. In addition, the more features children remembered, the more likely they were to retain the newly-learned name-object associations. Vocabulary size, however, was not predictive of children's feature memory or retention. Taken together, these findings demonstrate that children's existing vocabulary structure, rather than simply vocabulary size, influences what they attend to when encountering a new object and subsequently their ability to remember new name-object associations.

Learning what to remember: vocabulary knowledge and children's memory for object names and features

When acquiring language, children learn the meanings of many words. Children are highly skilled at determining the referent of a novel name when they encounter a novel object among several known objects (cf. "fast mapping" Carey, 2010).

However, without added supports they fail to recall these name-object associations after as little as 5 minutes (e.g., Gurteen, Horne, & Erjavec, 2011; Horst & Samuelson, 2008). In such cases it is unclear what—if anything—they remember about the novel objects.

In addition to learning object names, children must also learn which features are necessary for category membership, so that names can be generalized to new items. For example, to generalize CUP from a favorite pink sippy-cup, to mom's white ceramic mug or brother's green paper cup, a child must learn that shape, but not color or material, is relevant for CUP category-membership. From an early age, children can remember object features, but not all features are equally memorable. Kaldy and Blaser (2009) equated the salience of objects' shape, color, and luminance and found that 9-month-old infants recognized a change in shape or color, but not a change in luminance. Children can even remember a novel name for a feature over a short delay (Holland, Simpson, & Riggs, 2015). However, it is not clear what children recall about specific features when they learn a novel object's name.

Additionally, over development, children become biased to attend to some features more than others. In particular, they develop a 'shape bias' (Landau, Smith, & Jones, 1988) to generalize names of novel objects to other objects similar in shape, which emerges as a function of productive vocabulary *size* (Samuelson & Smith, 1999; and see Borgström, Torkildsen, & Lindgren, 2015). Vocabulary *structure* also

informs the development of word learning biases: how children generalize names—whether by shape or by material—varies depending on whether they know many names for categories well-organized by shape or material (Perry & Samuelson, 2011). However, word learning is fundamentally gradual (McMurray, Horst, & Samuelson, 2012) and cannot be fully understood by *only* examining in-the-moment attention during generalization. To understand word learning, it is necessary to examine how these processes interact with children's memory (see also Vlach, 2014). We therefore ask whether the structure of children's vocabularies also influences their memory for objects' names and features.

Here, we explore what children remember after forming initial name-object associations. Specifically, we examine which features children remember when it is unclear which feature is most relevant for category membership. Do individual children's memory for associations between names and object features (shape, color, material) differ with respect to their vocabulary size and structure? If vocabulary structure influences children's memory for novel objects, then, for example, children who know the most names for categories organized by shape should have the best memory for novel objects' shapes. We tested 24-month-old children because they are old enough to know many names for object categories (Samuelson & Smith, 1999), but young enough such that there is still sufficient variability between children to detect individual differences (e.g., Perry & Samuelson, 2011). We tested one age group to determine what effect vocabulary knowledge, independent of age, has on early word learning.

Method

Participants

Twenty-two 24-month-old monolingual English-speaking children ($M = 24\text{m}21\text{d}$, $SD = 51\text{d}$; range = 22m13d to 27m13d; 11 female) participated. Data from six additional children were excluded (four due to fussiness, and two due to experimenter error).

Children were randomly assigned to one of two between-subject conditions that differed in the presence of a 5-minute delay between referent selection and feature-memory trials to investigate whether this affected performance. Children were recruited from a database of interested families and each received a small toy for their participation. Testing took place in a quiet laboratory.

Stimuli

During the referent selection trials children saw nine known objects (e.g., duck, shoe) and three novel objects: a purple wooden cup-and-ball toy (*kiv*); a massager wrapped in green embroidery floss (*bem*), and a yellow spongey pom-pom (*fop*, all approximately 5cm x 6.4cm x 10.6cm, see Figure 1, leftmost column). The same known objects were presented on warm-up trials and the same three novel objects were presented again on retention trials. On feature-memory trials children saw cubes, orbs and clay objects sharing exactly one feature with the target novel objects. On material-match trials, children saw three pink cubes (5cm³) that matched the target objects in material (i.e., wood, embroidery floss, and sponge), but not color or shape. On color-match trials, children saw three polystyrene spheres (6cm x 8cm x 6cm) that matched the target objects in color (i.e., purple, green, and yellow), but not material or shape. The spheres were glued to square bases to prevent rolling. Finally, on shape-match trials, children saw three gray, clay objects that matched the target objects in shape, but not material or color. See Figure 1 second, third, and fourth columns for a

list of the shape-, material-, and color-matches, respectively. We intentionally used simple shapes on material- and color-match trials so as not to introduce new complex shapes that could interfere with children's memory for the novel objects. Stimuli were presented on a clear tray divided into three equally-sized sections.

Procedure

Every child first completed three warm-up trials where the same three known objects were placed on the tray and the child was allowed to view them for three seconds. The experimenter then asked for the target object by naming it five times (see e.g., Horst, Scott & Pollard, 2010) and sliding the tray forward. Across trials children chose objects from each position (left, middle, right). Positions were pseudo-randomized across children. After the child chose an object, the experimenter held up the target object and named it (e.g., Horst & Samuelson, 2008). The experimenter provided positive feedback (e.g., "you're right!") on warm-up trials, but not on subsequent trials.

Referent selection Using the same procedure, children then completed six referent selection trials. On each trial children saw one novel object (e.g., wooden cup and ball toy, or *kiv*) and two known objects (e.g., duck, shoe). Across trials children were asked for both novel and known objects (three each) to ensure children were not exclusively choosing novel objects. Trial order and object positions were pseudo-randomized across children.

Feature-memory Next, children completed nine feature-memory trials. Children in the 0-minute delay condition did this immediately after referent selection. Children in the 5-minute delay condition colored for 5 minutes between referent selection and feature-memory. On each trial children saw either all three shape-matches, material-matches, or color-matches and were asked for a target (e.g., "Where is the *kivvy* one?

Get the *kivvy* one.”). The original novel objects were not present during these trials. Adjectival syntax (e.g., *kivvy* one, rather than *kiv*) was used to indicate the child should select an object matching the recently presented target on a specific property. For example, *kivvy* referred to the cup-and-ball shape on a shape-match trial, the wooden cube on a material-match trial, and the purple sphere on a color-match trial. Trials were presented in blocks (e.g., all color-match trials consecutively, Figure 1). Block order and object positions were pseudo-randomized across children.

Retention Immediately after feature-memory trials, children completed three retention trials using the same procedure. On each trial, children saw all three original novel objects. Children were asked for each novel object once. Trial order and object positions were pseudo-randomized across children.

Vocabulary

Productive vocabularies were measured using parent report (MCDI; Klee, Marr, Robertson, & Harrison, 1999). Each word was coded in terms of category organization based on adult ratings (originally reported in Samuelson & Smith, 1999; Perry & Samuelson, 2011; Horst & Twomey, 2013). Raters judged whether a given word referred to a solid object or nonsolid substance and whether that category was organized by similarity in shape, material, or color (Samuelson & Smith, 1999). For example, CUP was judged to refer to a category of solid objects organized by shape, because shape is more important than material or color information in determining membership, and instances of the category are solid rather than nonsolid.

Based on these ratings, Perry and Samuelson (2011) examined three aspects of the vocabulary—shape-based, material-based, and against-the-system nouns—and the relationship between each aspect and novel noun generalization. Shape-based nouns name categories of solid objects organized by similarity in shape (e.g., ball),

categories organized by shape that use count noun syntax (e.g., sweater), and categories for solid objects that use count syntax (e.g., camera). Material-based nouns name categories of nonsolid substances organized by similarity in material (e.g., pudding, milk), categories organized by material that use mass syntax (e.g., snow), and categories of nonsolid substances that use mass syntax (e.g., soup). “Against-the-system” nouns are the exceptions to this divide between shape- and material-based nouns—such as *solid objects* in categories organized by similarity in *material* (e.g., chalk, ice). Against-the-system vocabulary predicts children’s attention to the material of solid objects (Perry & Samuelson, 2011). We only presented solid objects with count syntax; we therefore use shape-based nouns and against-the-system nouns to predict children’s memory for each object feature. We did not include a color vocabulary predictor because only three categories are organized by similarity in color, but not shape or material, (i.e., carrots, pickle, and pumpkin; Samuelson & Smith, 1999).

Coding and analysis

Experimental sessions were videotaped and coded offline. Twenty percent of sessions were re-coded for reliability. Inter-coder reliability was 100%. For the feature-memory and retention analyses we only included data for items that children had correctly selected during referent selection (see e.g., Axelsson, Churchley, & Horst, 2012; Horst & Samuelson, 2008; Kucker & Samuelson, 2012). We analyzed feature-memory in two ways: 1) using *t*-tests against chance to examine overall performance for each trial type (shape-, material-, and color-match), and 2) using logistic mixed regression to examine effects of vocabulary on feature-memory and retention. This approach has been used previously to demonstrate the relationship between vocabulary and novel noun generalization (Perry & Samuelson, 2011; Perry,

Samuelson, Malloy, & Schiffer, 2010). Each model includes random subject and item effects. Significance levels were calculated using chi-square tests comparing mixed-effect models with and without the factor of interest on improvement in model fit (Baayen, Davidson, & Bates, 2008).

We examined vocabulary structure by calculating the number of both shape-based and against-the-system nouns each child produced (based on Perry & Samuelson, 2011). We regressed out the total number of object nouns each child produced to measure vocabulary structure independent of size.

Results

Overall accuracy

As in previous studies, 24-month-old children were highly accurate on known name, $M = .92$, $SD = .20$, $t(21) = 12.66$, $p < .0001$; $d = 2.95$, and novel name referent selection trials, $M = .79$, $SD = .22$, $t(21) = 9.79$, $p < .0001$; $d = 2.09$ (Figure 2a). All reported means are proportion of correct trials.

Next, we examined the effects of delay (0 versus 5 minutes) between referent selection and feature-memory tasks on children's accuracy on the feature-memory trials ($M = .35$, $SD = .17$; $M = .32$, $SD = .25$, respectively) and on the retention trials ($M = .46$, $SD = .37$; $M = .54$, $SD = .25$, respectively). As the two groups did not significantly differ in overall feature-memory accuracy, $t(20) = 0.14$, $p = .89$, or retention, $t(21) = 1.48$, $p = .16$, we conducted all subsequent analyses on the combined sample.

As a group, children did not select the correct feature-match at levels significantly greater than chance on shape-match trials ($M = .39$, $SD = .31$), $t(21) = 0.86$, $p = .397$, $d = 0.31$; material-match trials ($M = .27$, $SD = .32$), $t(20) = -0.87$, $p = .40$, $d = 0.19$;

or color-match trials ($M = .32$, $SD = .37$), $t(21) = -0.15$, $p = .88$, $d = 0.03$ (see Figure 2b). Model comparison did not reveal any effect of block number, $X^2(1) = .89$, $p = .345$.

In contrast, as a group, children were able to retain the novel name-object associations at levels significantly greater than chance levels ($M=.50$, $SD=.31$), $t(21) = 2.58$, $p = .017$, $d = 0.55$ (see Figure 2b). It is unclear how answering incorrectly on the feature memory trials may have altered children's stored memory representations for the name-object associations (see Spiegel & Halberda, 2011 for a discussion). We therefore examined whether children's retention accuracy changed with the number of accurate feature-memory trials. We found a positive correlation between retention and the total number of features recalled ($M = 2.23$, $SD = 1.77$, range: 0-8), $r = .63$, $p < .01$. Thus, retention likelihood increases with the number of accurate feature-memory trials, but children generally have difficulty remembering individual features of novel objects.

Individual differences in vocabulary

Vocabulary size Previous studies have found a relationship between noun vocabulary size (MCDI sections 2-10) and attention to different object features (e.g., Perry & Samuelson, 2011; Samuelson & Smith, 1999). Children with larger noun vocabularies were generally more accurate at remembering the shapes of novel objects (see Figure 3). Additionally, these children were slightly less accurate at remembering materials and colors. Model comparison revealed a marginally significant interaction between feature-memory trial type and noun vocabulary size, $X^2(2) = 5.67$, $p = .059$ (see Coding and analysis section for model details). However, planned follow-up comparisons did not reveal any significant effects of vocabulary

size on the specific feature-memory trials (shape-match trials, $X^2(1) = 2.27, p = .132$, material-match trials, $X^2(1) = 2.57, p = .109$ or color-match trials, $X^2(1) = 0.41, p = .520$). Noun vocabulary size was associated neither with number of accurate feature-memory trials, $X^2(1) = 0.14, p = .705$, nor with retention accuracy directly, $X^2(1) = 0.28, p = .600$ (see also Horst, Scott, & Pollard, 2010; Kucker & Samuelson, 2012). Thus, although vocabulary size generally supports children's ability to remember novel objects' shapes, these effects are weak.

Vocabulary structure Next, we examined effects of vocabulary structure (i.e., shape-based nouns and against-the-system nouns) on feature-memory and retention trials. Children who produced more shape-based nouns were generally more accurate at remembering objects' shapes than children who produced fewer shape-based nouns (see Figure 4). Model comparison revealed a significant main effect of shape-based vocabulary, such that children with greater shape-based vocabularies had a greater number of accurate feature-match trials, $b = .09$, 95% CI [.01, .16], $X^2(1) = 4.11, p = .043$. In contrast, there were no significant effects of against-the-system vocabulary, $X^2(1) = .06, p = .804$, on overall feature-memory. Planned follow-ups revealed that the effect of shape-based vocabulary was driven primarily by performance on shape-match trials, as there was an effect of shape-based vocabulary on shape-match trials $b = .12$, 95% CI [-.005, .25], $X^2(1) = 3.98, p = .046$; but not material-match, $X^2(1) = 0.76, p = .382$, or color-match trials, $X^2(1) = 1.41, p = .235$. There were no effects of against-the-system vocabulary on shape, $X^2(1) = 0.72, p = .396$, material, $X^2(1) = 0.05, p = .822$, or color-match trials, $X^2(1) = 0.18, p = .669$.

Finally, shape-based vocabulary was associated with retention accuracy, $b = .14$, 95% CI [.003, .28], $X^2(1) = 4.89, p = .027$; but against-the-system vocabulary was not, $X^2(1) = .70, p = .403$. Thus, vocabulary structure—particularly shape-based

nouns—contributes to children’s ability to remember objects’ names and features independent of vocabulary size. Figure 5 presents a pictorial representation of the connections between vocabulary, feature memory, and retention.

Discussion

The current study explored children’s memory for the features of recently encountered objects and the roles vocabulary size and structure play on children’s retention of novel name-object associations. Following referent selection, children generally had difficulty recalling objects’ features. However, children who produced more shape-based nouns—*independent of vocabulary size*—performed significantly better on the feature-memory trials and retained significantly more name-object associations. These findings demonstrate that vocabulary *structure* confers advantages for retention of fast-mapped words above and beyond vocabulary *size*.

Our findings are consistent with previous studies demonstrating no significant effect of vocabulary knowledge on children’s retention from fast mapping (e.g., Horst & Samuelson, 2008; Kucker & Samuelson, 2012). Critically, the current study provides novel insight into why children are poor at retaining novel words after fast mapping (e.g., Axelsson et al., 2012; Horst & Samuelson, 2008; Munro, Baker, McGregor, Docking, & Arculi, 2012): children with smaller shape-based noun vocabularies were less likely to remember objects’ shapes and subsequently less likely to retain novel name-object associations. This finding suggests that vocabulary structure influences whether some object features remain in memory shortly after an initial presentation. Children retain novel words better after fast mapping when provided with additional supports, such as repetition (e.g., Axelsson & Horst, 2014; Gurteen et al., 2011), multiple memory supports (e.g., Vlach & Sandhofer, 2012) or

semantic cues (e.g., Capone & McGregor, 2005). These supports might aid retention because they help children remember the objects' features. Across development, children are increasingly able to encode combinations of features (Oakes & Madole, 2003), which in turn supports object identification. Together, vocabulary structure and the capacity to integrate multiple features appear to be important for long-term word retention.

Limitations and future directions

As children typically demonstrate the shape bias around 24 months (Landau et al., 1988), why were children in the current study, as a group, unable to remember objects' shapes? Novel noun generalization tasks test label extension; they do not present memory demands on the child because the *original exemplar is always visible*. Our task, however, tests recall because the original object is no longer visible. Unless their vocabularies are dominated by shape-based nouns, children may have difficulty remembering shape after a single encounter with a novel object. Increased memory demands in our task relative to a generalization task may also explain why we did not find a material-memory advantage for children with larger against-the-system vocabularies (as in Perry & Samuelson, 2011). Future research should explore how memory biases develop over a more protracted slow-mapping process.

Overall, children who remembered more object features were more accurate at retaining the name for that whole object. One explanation for this relationship is that the same processes underlie both featural and holistic encoding. Another possibility is that feature-memory trials provide an additional learning opportunity, reinforcing memory of name-object associations (cf Vlach, Ankowski, & Sandhofer, 2012). Manipulating the number and order of feature-memory and retention trials may be

useful for exploring the relationship between remembering name-feature and name-object associations.

The current findings demonstrate that vocabulary structure influences children's memory for novel objects' features and names. Future research is needed to determine whether children's early memory or attentional biases lead them to acquire a vocabulary with a given structure, or whether acquiring a vocabulary with a given structure leads children to develop certain biases. Although longitudinal training studies demonstrate that vocabulary knowledge drives attentional biases (e.g., Perry et al., 2010), an important future question will be the directionality of the relationships between vocabulary, memory, and attention.

Conclusions

The current findings illustrate how vocabulary structure—independent of vocabulary size—influences what children remember immediately after fast mapping and how that affects retention. Importantly, considering vocabulary size alone is insufficient to explain the likelihood of an individual child retaining novel name-object associations following fast mapping. Both vocabulary structure and feature-memory have cascading consequences for children's subsequent word retention.

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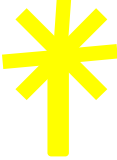


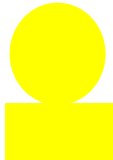
Word	Target object	Shape match	Material match	Colour match
Kiv	 Purple wood cup-and-ball	 Clay cup-and-ball	 Pink wood cube	 Purple sphere
Bem	 Massager in green embroidery floss	 Clay massager	 Pink embroidery floss cube	 Green sphere
Fop	 Yellow sponge pom-pom	 Clay pom-pom	 Pink sponge cube	 Yellow sphere

Figure 1. The left most column shows the novel words and illustrations of novel objects used on referent selection trials. The three columns to the right show illustrations of shape matches, material matches, and color matches (respectively) to novel objects from referent selection trials used on feature-memory trials.

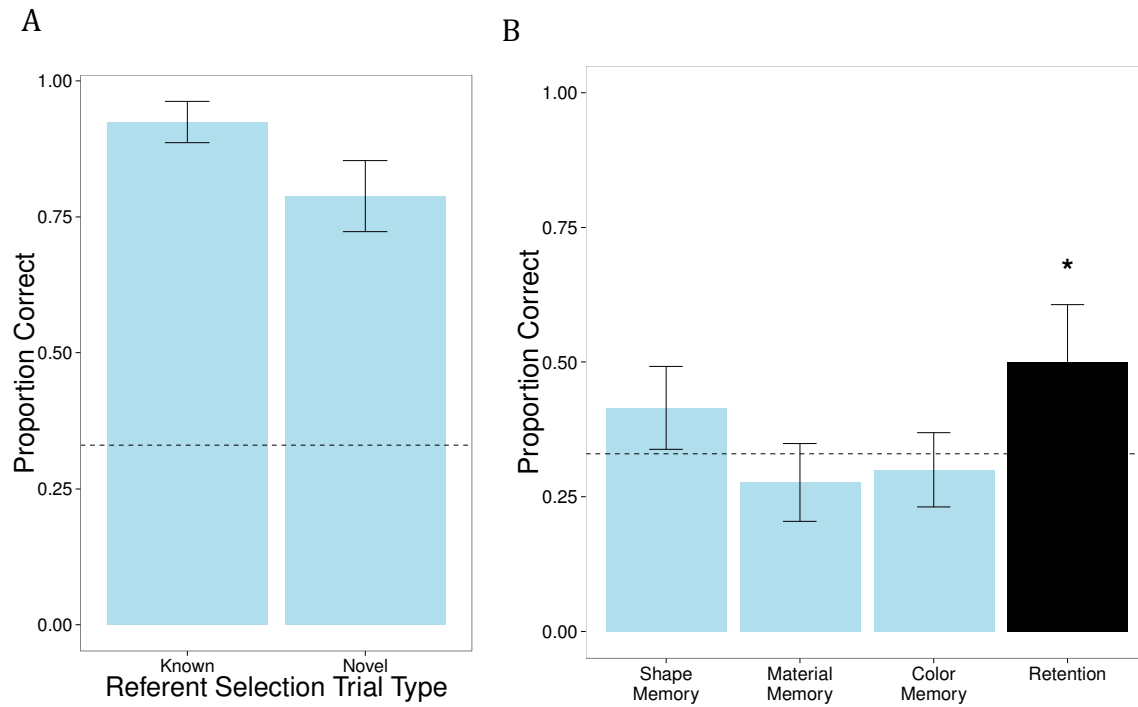


Figure 2. (A) Proportion of correct choices on referent selection trials for known and novel objects. (B) Proportion of correct choices on shape-match, material-match, and color-match feature-memory trials and proportion of correct choices on retention trials. Error bars depict standard error of mean. Dotted lines represent chance (.33). * indicates performance significantly better than chance ($p < .05$).

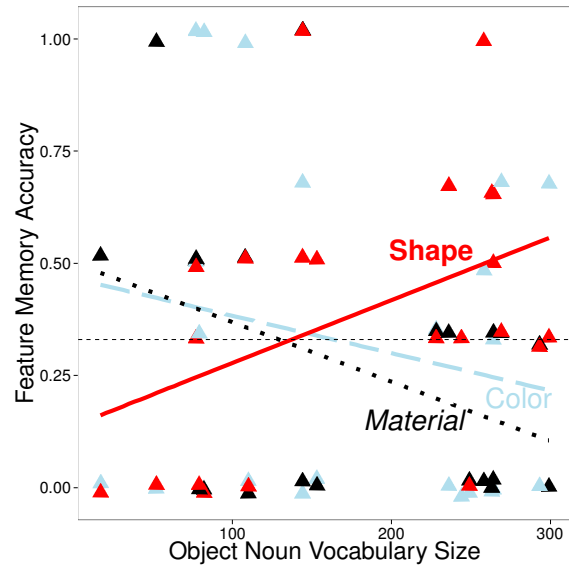


Figure 3. Relationship between vocabulary size and proportion of correct choices for each feature-memory trial type. Shapes are for visualization purposes to facilitate comparison of trial types for individual children.

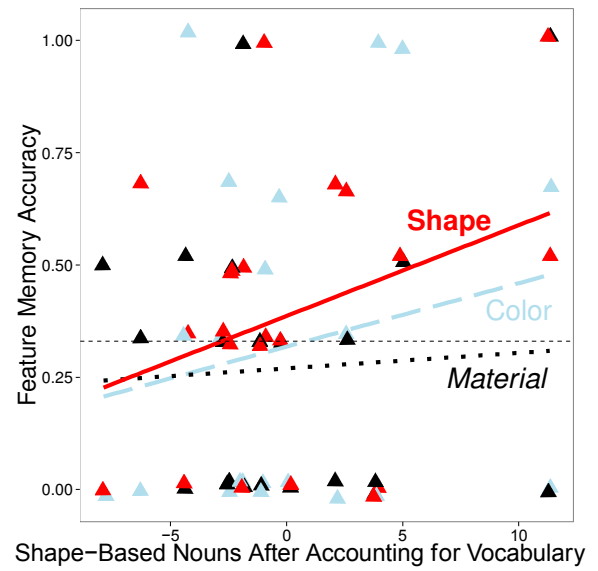


Figure 4. Relationship between vocabulary structure and proportion of correct choices for each feature-memory trial type. Vocabulary structure is measured by taking the number of nouns children say on the shape side of the vocabulary, and regressing out total noun vocabulary size (see Samuelson & Smith, 1999; Perry & Samuelson, 2011). Shapes are for visualization purposes to facilitate comparison of trial types for individual children.

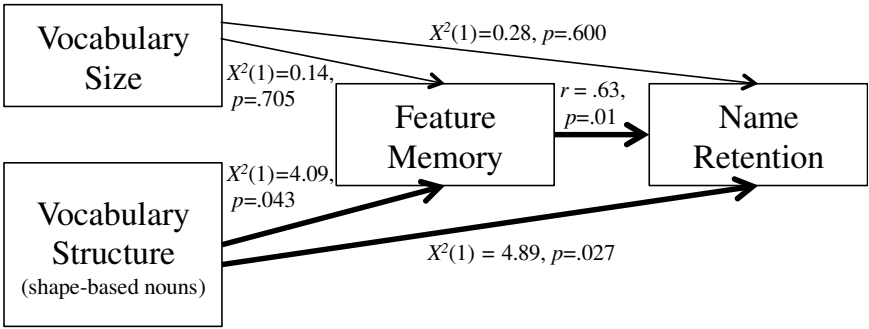


Figure 5. Relationships between vocabulary size and structure (as measured by shape-based nouns), feature memory, and name retention. Lines in bold refer to significant relationships in the current study.